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A Quantitative Analysis of the Impact of Wind Energy Penetration on Electricity Prices in Ireland

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A quantitative analysis of the impact of wind energy penetration on electricity prices in Ireland

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Abstract

The maturity of wind technology combined with availability of suitable sites means Ireland is on course to generate 40% of its electricity from the wind by 2020.This work sets out to quantify, to what degree, if any, increased wind penetration translates into reduced wholesale and retail prices for electricity. The consensus from the literature is that increasing wind penetration reduces wholesale electricity prices, but views vary as to what degree this translates into reduced retail prices for the consumer.

This work demonstrates the effect of wind energy penetration on the price of electricity in Ireland using quantitative data from the market and grid operators. An analysis of the data reveals that increasing wind penetration is having little impact on average prices.

This work concludes that, due to the fact that imported UK gas powered generation is the main (48%) form of electricity generation in Ireland, the changes in Irish wholesale electricity prices are primarily determined by UK gas prices and that increases in wind penetration in recent years have not affected this relationship. This, and the presence of a minimum tariff received by producers, enables wind energy providers to compete on price, representing a sound commercial basis for investment in renewables, while continuing the trend of reduced, imported fossil fuel, dependence in Ireland.

Keywords: Wind energy penetration; Wholesale electricity price; Retail electricity price; Ireland.

1. Introduction

Irish policy on electricity markets and targets for renewable generation are primarily directed by EU policy and international targets [1]. Ireland is seeking to supplant a large proportion of its, predominantly fossil fuel based, electricity generation capacity with renewables in order to fulfil its requirements under EU directive 2009/28/EC in which the EU is seeking to source 20% of its total primary energy requirement from renewable sources by 2020. In order to achieve the target, laid out under 2009/28/EC, the government of Ireland have set a target of 40% of electrical system demand to be met by renewable sources by 2020 [2]. Ireland's technical wind energy resource was estimated at 613 TWh per year compared to Ireland's annual electricity consumption of 27 TWh in 2003 [3]. Figures from the current work show that annualised wind energy generation met a mean of 18% of system demand in Ireland in 2013 [4].

The aim of this study is to examine the effect of wind energy penetration, wind generation as a percentage of demand, on both the wholesale and retail prices of electricity in Ireland.

A literature review will establish the extent of the impact of wind penetration on the price of electricity based on international and national studies.

This work shall then present historical trends in wind penetration and system marginal price (SMP), based on data gathered from the transmission system operator and single electricity market operator [4-6]. These are then averaged over daily, weekly and monthly periods. In addition data on UK natural gas prices is collected from the commodity trading website www.theice.com [7].

Historical trends in retail prices for the two most common price bands in Ireland will also be presented and compared with the retail prices in Denmark. This data is available from the sustainable energy authority of Ireland (SEAI) [8]. Denmark is chosen as it has a higher level of wind penetration than Ireland. Current trends in Denmark may give an indicator of the future direction of the Irish market.

1.1. Background

48% of electricity produced in Ireland is from imported gas, while up to 80% is from imported fossil fuels [9]. Ireland has one of the highest dependencies on imported fossil fuels for electricity generation in Europe which is why it's electricity prices are generally higher than other European countries, for example France, which has large amounts of nuclear, or Norway, which has large amounts of hydro. Since imported fossil fuels have such an influence on Irish electricity prices this suggests that there is a strong linkage between electricity prices and global oil prices. Table 1 shows that Ireland has a target of 40% of electricity production from renewable sources as a major contributor to achieving its overall target under its national renewable energy action plan (NREAP).

Table 1. Ireland's renewables share and targets under NREAP[2].

												Targets	
% of each Target	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2010	2020
RES-E	**4.9**	**4.1**	**5**	**6.8**	**8.6**	**9.4**	**11.9**	**14.4**	**14.8**	**16.8**	**19.6**	**15**	**40**
RES-T	0	0	0	0	0.1	0.5	1.2	1.5	2.6	3.6	3.8	3	10
RES-H	2.6	2.1	2.4	3.5	3.6	3.7	3.6	3.9	4.4	5	5.2	5	12

1.2. Impact of renewable generation on electricity prices

The relative maturity of wind technology and ready availability of suitable sites means that wind energy will have the greatest impact on Irish electricity prices when compared to other renewable sources [10]. Due to the vagaries of wind, wind power comes at a cost [11] and, in general, the higher the commitment to wind power in a system, the more costly the uncertainty of wind generation becomes. This is because expensive fossil fuel powered plants must be ramped up at short notice [12, 13]. It has therefore been accepted that while wind energy will displace conventional thermal plant, it will only have a limited capacity, as in order to maintain system security and flexibility, there is a need for a significant conventional capacity to remain on the system [14]. The conventional plant will have lower load factors, which will increase their costs and reduce profitability. Operators will have to provide other payments to ensure system security, and it is likely these indirect costs will be passed onto the consumer as network costs.

An examination of the Spanish market from 2005 to 2007 concluded that the reduction in wholesale prices, due to increased penetration of renewables, is greater than the increase in consumer cost due to necessary support mechanisms, with a reduction level of between 9% and 25% from 2005 to 2007 [15]. Jensen and Skytte showed that substituting conventional with renewable generation reduces wholesale prices as renewables have lower variable costs, and can bid in at a lower or zero cost [13, 16]. Felder concluded that if 100% of demand was supplied by renewable sources, wholesale energy prices would be close to zero, but consumer electricity costs may increase to provide for the extra costs associated with transmission upgrading, system support, reserve capacity and integration etc. [17]. A study of the UK market showed it will not be possible to displace conventional plant with renewable generation on a one for one basis [14] as there are extra costs associated with reserves and extra ancillary services also. The study concluded that the system can accommodate significant levels of wind generation with only small increases in the cost of electricity to the consumer. The added costs are driven by higher capital costs for support mechanisms, which indicated 5% net additional costs on domestic electricity price. A study of the German market has concluded that the cost benefit of increasing renewable power penetration would be significant and exceed the costs of support mechanisms. It highlights the saving on fossil fuels but also the challenges and costs associated with increasing renewable generation [18].

The electricity markets in Ireland, North and South, are merged into a single entity known as the single electricity market (SEM). The SEM is essentially a pool that generators bid into and suppliers buy out of [19]. The marginal generator is the highest bid generator that meets demand for that half hour period and sets the system marginal price (SMP) for that half hour period. There is a large proportion of natural gas in Ireland's fuel mix which is used in either combined cycle gas turbine (CCGT) plants, which are used because of their high thermal efficiency, or open cycle gas turbine plants (OCGT) which are less efficient but have lower capital costs.

An Irish wind energy association (IWEA) report carried out by Redpoint in 2011 tried to predict the impact of increased wind penetration on SEM prices by 2020. It concludes that CCGT will remain the marginal, i.e. SMP setting, plant, but will lose market share when wind output levels are high. By 2020 during periods of high wind output and low demand, all electricity may be supplied by wind generation, thus reducing wholesale prices to zero during these periods. It concludes that wind generation may supply total demand for 500 hours during 2020 and in 200 of these, excess demand shall be exported to the UK, thereby ensuring the SMP is above zero. The average generation cost will reduce as more expensive thermal plant is displaced by renewables, but the effect on price is not as significant, as CCGT will remain the marginal plant. As electricity demand has fallen since late 2008 and 800MW of new CCGT has been commissioned, the SMP is rarely set by more expensive OCGT or oil plants. The net benefit to the customer from increased wind penetration will be a saving of €38/year by 2020 [20].

The merit order effect (MOE) occurs when low marginal cost generation replaces higher marginal cost of conventional plant, e.g. the fuel source for wind power is free making it cheaper when compared to conventional generation [21]. A German study [22] shows that in terms of fuel prices, nuclear and coal prices have a minor effect, as they are mostly base load plant, which are not replaced through renewable generation. The study shows gas price impacts on the MOE because gas fired generators are generally the marginal plant, setting the SMP and that the MOE increases with the installed renewable capacity.

A study by Finn et. al. highlighted that as wind penetration increases, up to 12.75% of trade periods could require curtailment if the system is not improved thus increasing costs [19]. The most economic level of wind penetration with oil prices of $110/barrel would be 30%, which is also the most technically feasible level for the Irish grid system [23].

A report for the Irish commission for energy regulation (CER) and the Northern Ireland authority for utility regulation (OFREGNI) in 2003 examined increased wind energy penetration. It examined costs with curtailment necessary to ensure conventional plant remains running a minimum load and predicts curtailment costs would be zero up to 1000MW installed capacity, small curtailment costs up to 2000MW and becoming significant above 2000MW [24]. The report concluded fuel savings from the displacement of conventional generation would amount to the largest saving, estimated at €75 million per year for the first 1000MW. Transmission losses are increased with more wind penetration due to distances to the consumption areas, losses are put at 0.5% with 2000MW installed capacity.

The CER carried out an all island grid study into the impact of large levels of wind penetration on electricity prices by 2020. The study assessed the technical feasibility, benefits and costs by 2020 of five generation portfolios with levels of renewable penetration ranging from 23% to 59%. Assumptions include a 1000MW UK interconnector, no network restrictions, CO_2 price of €30/t and a gas price of €22/MWh. Also capacity payments, ancillary services and reserve payments will be required to make up the difference between the SMP and annualised investment costs.
It concluded that:

- Wholesale prices will reduce regardless of carbon and fuel costs, except in a portfolio with increased levels of OCGT penetration.[25].
- Given the large variation in renewable penetration the cost varies only by 7% between the five portfolios. This suggests that wind generation can be treated as a “price taker”.
- Renewable generators could recover 70-80% of their investment costs from the market, while the remainder would be required from support mechanisms.
- Generation portfolios with high renewable shares can result in greater price risk due to variability of supply but there is a lower exposure to fluctuations in fossil fuel price [26].

The cost of generating electricity in power plants currently accounts for about 60% of the Irish consumer’s electricity bill. This consists mainly of fuel and network costs. Network costs are increased due to low population density which means more cable is required per consumer (84m/customer compared to 49m/customer in the U.K.). Since the market is deregulated suppliers compete directly on price to gain market share. An additional cost is a government initiative called the public services obligation (PSO) levy which places an obligation on participants to purchase renewable (and also peat derived) energy and to finance schemes such as the renewable energy feed in tariff (REFIT) which assist in developing projects to meet Ireland’s 40% target by 2020. Any difference between the price received by the generator and REFIT is reimbursed/levied through the PSO. The CER sets the PSO levy annually based on projected revenues and when actual revenues are known the supplier is reimbursed/levied for any outstanding amount. Total PSO payments are predicted to be €205.6m for 2013/2014, an increase of €74.4m over the 2012/2013 figure [27]. REFIT is set at €69.581/MWh in 2013/2014.

A joint report by, Irish transmission service operator, EirGrid and the Sustainable Energy Authority of Ireland (SEAI) concluded that expected levels of wind generation would reduce wholesale electricity costs by €74 million in 2011 compared to a scenario with no wind generation. However these savings would be almost equal to the extra costs associated with the PSO support mechanism and increased constraint costs due to wind generation [28]. The report concluded wind energy can be utilised to offset high fuel costs by reducing the average SMP, by approximately €2/MWh in a 2011 wind scenario. Reports carried out by the ESRI attempted to estimate the cost of renewable support mechanisms such as REFIT in terms of electricity prices in the year 2020. They concluded that the cost adds approximately 5 – 10% to the wholesale price and this increases significantly with the addition of offshore wind, wave and tidal to the generation mix due to the higher tariff payments [29].

2. Results

Table 2 shows the historical trend in the fuel mix for electricity generation in Ireland. This shows that natural gas makes up the largest proportion (48%) while the combination of gas and renewables comprise 72% in 2012. This suggests that natural gas, in particular gas used in CCGT plant, will largely determine the SMP in Ireland.

Table 2: Fuel mix for electricity generation in Ireland. Numbers may not sum to 100% because of rounding. Other includes Oil,Nuclear [9]

	2005	2006	2007	2008	2009	2010	2011	2012
Coal	24	19	18	17	14	16	14	20
Gas	46	50	55	61	62	64	56	48
Renewables	9	11	11	11	14	12	17	24
Peat	8	7	6	7	7	6	6	7
Other	13	13	10	5	3	2	7	2

Fig. 1 shows a comparison of weekly averaged SMP in Ireland and UK National Balancing Point on a month to date basis. The similarity of the pattern in the two plots reinforces the idea of gas price as the main determinant of SMP which was suggested in Table 1.

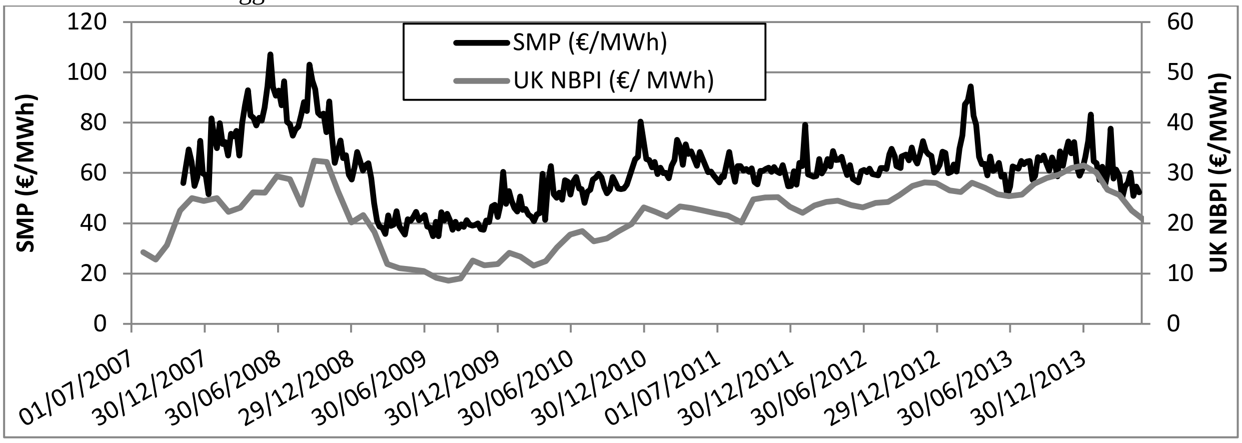

Fig. 1. Comparison of Irish Wholesale electricity and UK gas prices from 2007 to 2013.

Fig. 2 shows a comparison of wind penetration vs. SMP. It is difficult to spot a definite pattern in the data. Both wind penetration and SMP rise from early 2009 on. Since wind penetration is not the sole determinant of SMP it cannot be stated that there is a definite relationship. A yearly average of wind penetration shows that there was an average wind penetration of 6.7% in 2007 compared to 18% in 2013.

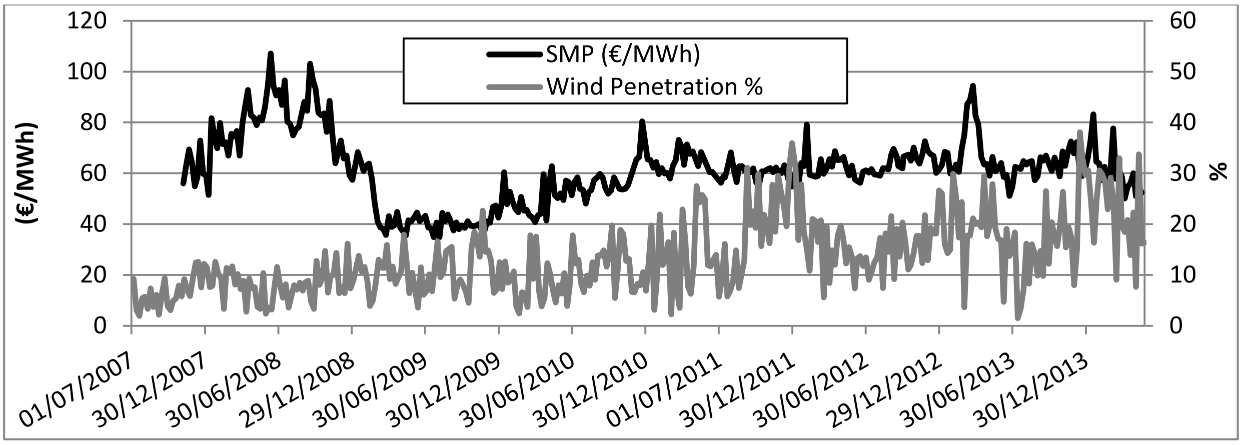

Fig. 2. Comparison of System Marginal Price and Wind penetration.

2.1 Comparison with Danish data

The Nordpool Elspot market is a day-ahead electricity market and it is the physical delivery market for electricity, operating in Scandinavia. It includes Denmark, Finland, Sweden and Norway and the region in North East Germany served by the Kontek interconnector [30]. It has one of the highest installed capacities of wind energy in the world and it is likely that the effects of renewables on this market and its prices would be evident and similar to other markets with high levels of wind generation[12]. For this reason Danish electricity prices, are used to provide a comparison with the Irish market. As the Danish system has higher levels of wind penetration it may give indicators as to what will happen as levels of wind penetration in Ireland increase (see Fig. 3).

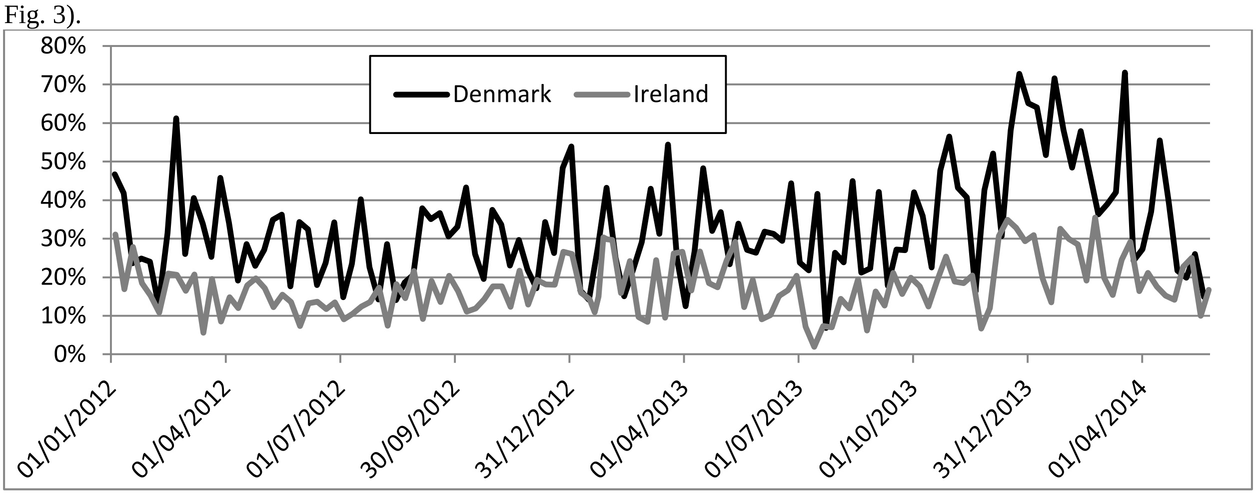

Fig. 3. Comparison of the levels of weekly averaged wind penetration in Ireland and Denmark

Figure 4 is a representation of the trend in domestic and industrial electricity prices in Ireland over the years from 2007 to 2013. The graph is of consumption band DD (2500 kWh – 5000kWh) and band IB (20-500MWh) which are the most commonly used ones. It shows a peak in 2008 followed by a drop in 2009. There has been a steady increase since 2011. The SMP has not reached the peak levels of 2008 whereas retail prices have. The corresponding figure for Denmark shows a much wider disparity between domestic and industrial prices. Overall there is a small increase in both retail prices over the time period.

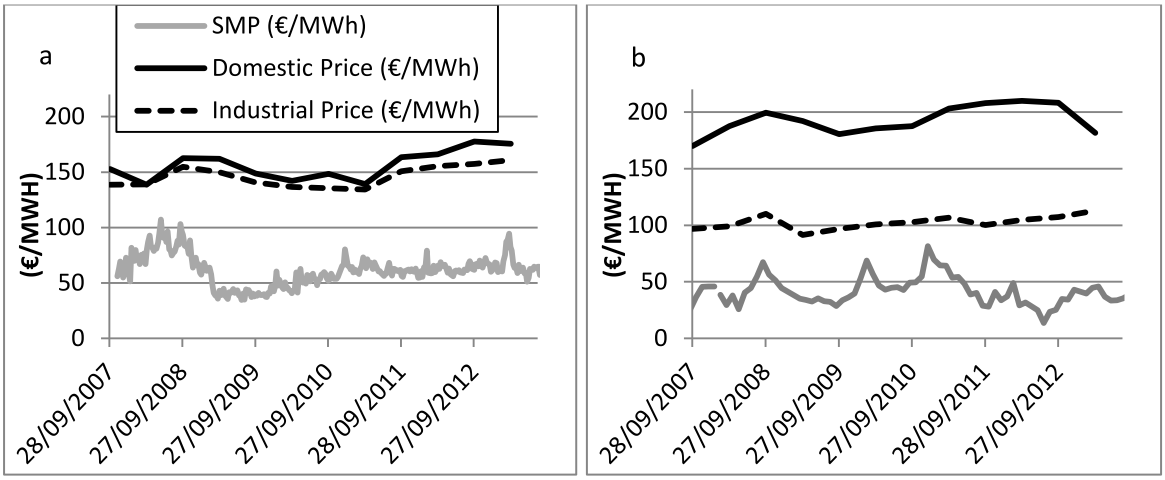

Fig. 4. Domestic (band DD) and Industrial (band IB) electricity prices in a) Ireland b) Denmark

3. Conclusions

Ireland has enormous untapped potential wind power resources and this will need to be availed of in order to reduce carbon emissions in order to reach Ireland's targets under directive 2009/28/EC. In addition Ireland is heavily dependent on imported fossil fuels and wind power will help reduce this.

The authors have presented historical trends of the levels of wind penetration, system market price (SMP) and the most common retail prices in Ireland. The data show a steady increase in the fraction of system demand being met by wind, from 6.7% in 2007 to 18% for the year 2013.

The predominance of natural gas in the fuel mix for power generation in Ireland suggests that this will have a significant influence on wholesale electricity prices. This is borne out by the data which suggests a correlation between the two. In addition the necessity to have a 'hot reserve' to counteract variability in the wind means that gas powered generation tends to be the marginal plant in Ireland setting the SMP.

In addition data from the Danish market, which has significantly higher levels of wind penetration, does not suggest a strong correlation between, levels of wind penetration and electricity prices in general.

The predominance of natural gas as the marginal plant and the presence of a minimum price received by the producer should serve as a very strong incentive to investment in wind energy in Ireland which should help to maintain the strong level of growth in wind energy generation in Ireland. This is necessary to meet carbon emission targets and also to reduce dependence on imported natural gas. Previous studies and the current work suggest that this increase in wind penetration should not affect pricing of electricity in Ireland into the future.

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